THE DEVELOPMENT OF PRODUCT DISTRIBUTION SYSTEM FOR NEW DISTRIBUTION CENTRES USING SIMULATION TECHNIQUES

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ABSTRACT

This study is to develop the product distribution system for three new Distribution Centers(DCs) in Chiang Rai, Thailand according to no historical data and no experience at the new DCs.Thedeveloped system will be used to evaluate the capability of the systemsassociated a question on the increasing arrival product volumes from the southern region of China.The exponential distribution and triangular distribution techniques are proposed tovary on the modules of the developed systems for simulation and evaluation. Chiang Khong, Chiang Sean and Mae SaiDCs in Chiang Rai province, Thailand arethe case study. Two product distribution systems were developed; Chiang Khong and Mae Sai system of road transportation and Chiang Sean system of waterway-road transportation. These two systems weresuccessfully developed and the capability of the systems was described subtly. The bottleneck problem causing a long queue ofwaiting trucks reflected on the systems efficiency.

KEYWORDS

Product Distribution Analysis, Product Distribution Model, Modelling Product Distribution Capability System for New Distribution Center

1. INTRODUCTION

Rapid economic growth of China obviously causes an increasing demand of product distribution. Yunnan province, the south territory of China, is one of major agricultural producers that requires its products transporting to global market. However, its location is in an isolated area surrounding by steep mountains. It is an obstacle to distributing its products to Chinese seaports. This reason leads to initiate the North South Economic Corridor (NSEC) originating from the southern region of China to Thailand. At Chiang Rai province, the northern border of Thailand, three new DCs have been constructing in Chiang Khong district, Chiang Sean district and Mae Sae district in order to facilitate product distribution originating from Yunnan through the global market as shown in Figure 1.

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Figure 1. Transportation route from the south of China via Thailand to global market [11]

To understand the system behaviors and to evaluate the capability of the systems before implementation to prevent the unexpected problems occurring in the real systems, ARENA application is one of the simulation applications that efficiently simulates the system capability as in Figure 2 and it is used to analyze the changing of the system behaviors [6],[7]. According to the comprehensive reviews [1], [4], [5], [8], [12], [13], [14] [15], [16], [17], this application is widely used in many field areas such as manufacturing, inventory and warehousing, product distribution, and supply chain management in order to improve the system performances, to determine the best alternative performance of warehouses, and to indicate and monitor the logistic behaviors for analyzing the real system.

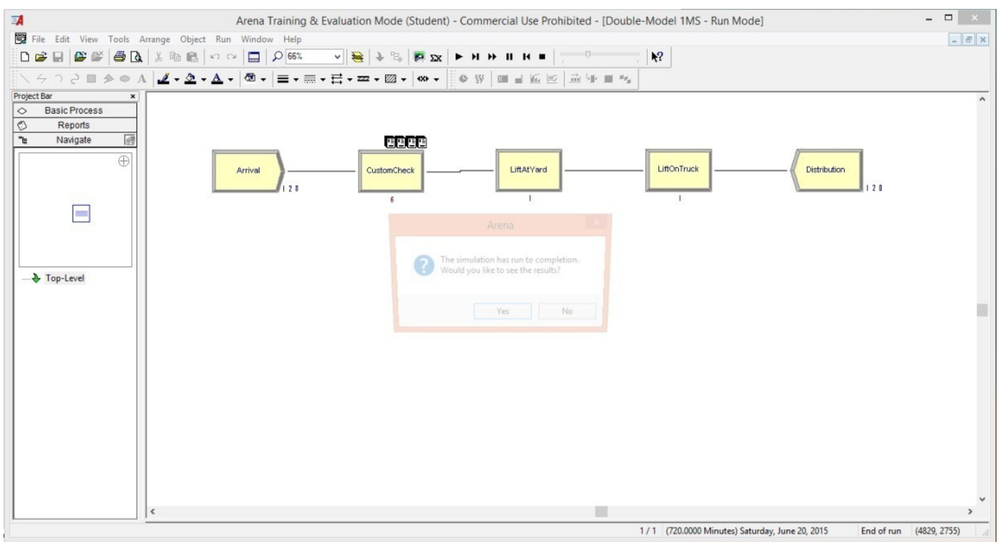

Figure 2. User Interface of ARENA application during simulation

With the efficiency ofARENA application, itis applied to develop the modelfor describing the capability of the system, and it will support to simulate the proposed scenario to define the increasing arrival product volume from the southern territory of China. We expect that the proposed scenariocan evaluate the system capability and the developed system can possibly reflect the problem in the system of these new DCs when arrival products are increased. Finally, the solution for the developed system can be proposed and the developed system can contribute for use in other similar systems.

2. RESEARCH OBJECTIVES

The specific objectives in this study comprise of (a) developing a product distribution system for the new DCs in order to explain the system capability, and (b) reflecting the possible problem in the product distribution system when it is operated in order to propose the solution for improving the system capability efficiently.

3. RESEARCH LIMITATIONS

This paper context only concerns on the product distribution systems of three new DCs (Chiang Khong, Chiang Sean, and Mae Sai district in Chiang Rai province, Thailand). The regular working time of the systems is between 06:00 to 18:00 or 12 hours a day. The product distribution system of Chiang Khong and Mae Sai DCs facilitates for road transportation while the Chiang Sean system facilitates waterway transportation for arrival and distributes the products by road transportation. All products are assumed to contain in containers and these containers will be transported out from the systems by trucks. One container fits for one truck and its weight is 20tons.

4. METHODOLOGY

This section will provide the fundamental concepts for developing the product distribution systems of the new DCs such as the field observation and data collection, the model development, and the model application. In detail, the ARENA application is used to develop the systems based on the field observation and the data collection. Simulation techniques (the random exponential distribution and triangular distribution techniques) are applied to simulate the developed systems as virtual as possible.

4.1. Field Survey and Data Collection

Due to the study area at Chiang Khong, Chiang Sean and Mae Sai DCs in Chiang Rai province, Thailand, the field survey and data collection were completed to understand their product distribution systems.

4.1.1. Field Survey

As surveyed, Chiang Khong and Mae Sai DCs function to faciliate the arrival products by road transportation passing by Lao PDR at Chiang Khong DC and by Myanmar at Mae Sai DC as in Figure 3 and 5. However, with the same function of both DCs, the size of Chiang Khong facilities is bigger than Mae Sai DC. After the field survey, the operation processes of the product distribution system of both DCs comprise of the custom check service point, storaging the arrival product at the container yard, distributing a container of arrival product by a provided truck.

Figure 3. Chiang Khong DC location (Source: www.cm108.com)

Arrival products that arrive at the DCs are contained in containers. After finished processing in the DCs, the provided trucks are ready to facilitate these containers delivering to Chiang Rai road network. The working time is 12hours per day between 06:00 and 18.00. We notice that the field survey can help us to draw the operations of the product distribution systems in Chiang Khong and Mae Sai DCs. The operational processes in these DCsare the custom check service counter, storaging the arrival containers at the container yard, delivering a container of arrival product bythe provided trucks.

In Chiang Sean DC, it functions to facilitate the arrival products transporting by waterway transportation. Then these products will be released from the DC by road transportation. The operation processess of Chiang Sean product distribution system composes of lifting arrival contatiners from a ship, checking at the custom check service point, distributing a container of arrival product by an available truck. In Figure 4 and 6, it is the infrastructure of Chiang Sean DC.

Figure 4. Chiang Sean DC location [3]

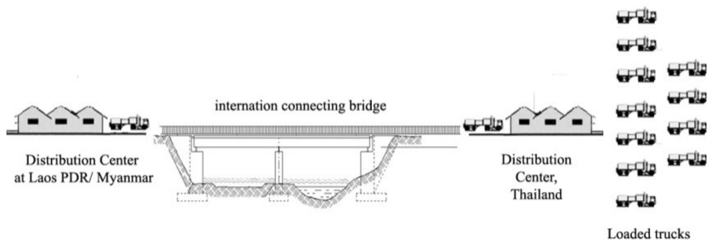

Figure 5. Structure of road transportation at Chiang Khong and Mae Sai DCs [12]

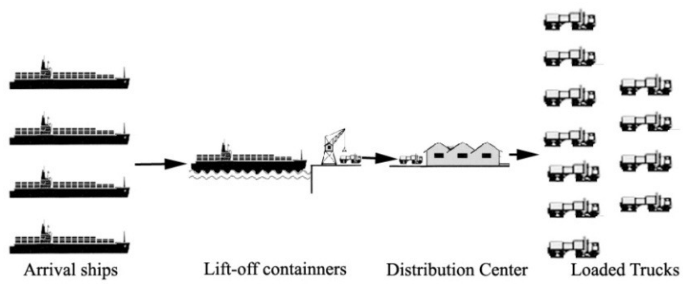

Figure 6. Structure of waterway and roa transportation at Chiang Sean DC [12]

From the field survey, the operational processes at these three DCs are subtly designed, and the infrastructure of the DCs can be estimated for providing the service.

4.1.2. Data Collection

The data of arrival products from the southern region of China to Chiang Khong custom house in year 2012, Chiang Sean custom house in year 2009, and Mae Sai custom house in year 2012 were collected as shown in Table 1. The annual report of Chiang Khong and Mae Sai custom houses were the sources of the data collection [2], [9] as well as Marine Department [10] providing the arrival product volumes of Chiang Sean custom house.

These historical data will be used as the base data of the arrival product volume of the new DCs. However, the arrival product volumes entering at the new DCs expect to increase unknowingly. Before the new DCs will be able to implement, the capability of the system requires to be studied.

Table 1. Arrival products at ChiangKhong, Chiang Sean, and Mae Sai custom

Month	**Custom**		
	Chiang Khong in 2012	**Chiang Sean in 2009**	**Mae Sai in 2012**
January	25,540	18,268	11,542
February	32,280	9,467	12,688
March	29,160	9,752	8,437
April	26,780	9,354	12,676
May	35,020	14,407	4,941
June	29,460	16,266	26,353

July	39,700	29,251	5,078
August	39,080	29,223	4,103
September	30,740	47,448	3,508
October	34,720	51,148	5,659
November	37,560	51,001	8,783
December	34,480	37,510	9,865
Total	394,520	323,095	113,633

4.2. Model Development

Based on the field observation and the data collection,two product distribution systems are developed. The first system is provided for road transportation, and this system is designed forChiang Khong, and Mae Sai DCs that areapplied as the case study.Another system is developed for distributing products by waterway-road transportation and Chiang Sean DC is the case study of the developed system.In Figure 6 and 7,both figures show the fundamentalmodulesthat function in the developed systems, and the system are processed as First-In First-Out (FIFO) queue.Products arriving at these two systemsare contained in containers.Containers will beoperated sequentially and immediatelywhen the systems are available; otherwise these containers need to wait in a queue.

Inaddition, Figure 6describes the system processesof the Chiang Khong and Mae SaiDCs. There are four major modules in this system; "Arrival", "CustomCheck", "LiftAtYard", and "LiftOnTruck" modules. The first module("Arrival")is to identify the arriving time for each container entering the system.The simulation technique that is the random exponential distribution is used to manage the interval of arriving time for the system.

The "CustomCheck" module and other process modules will use the triangular distribution technique for specifying the maximum processing time, the delay time and the minimum processing time. Following the FIFO queue, ifthe "CustomCheck" moduleis idle, the arriving container with the list of invoice will be lodged at the Customs servicecounter. The invoice list will be verified. Then, the import invoice will be generated. If failing verification, the list of invoice will be returned for modification. After that, the import invoice is needed to be paid.

The next module is the "LiftAtYard" module. This module is to declare the products and the payment. Then,declared containers will park at the container yardwaiting for provided trucks.
The "LiftOnTruck" module is the last module that will verify the payment and containers. After that, the completed containers will be loaded on the provided trucks, and the containers are done processing in system. The containers will leave the system at "Distributing" module through the road network.

On the other hands, Figure 7details the major modules of Chiang Sean system including the sub-modules. As mentioned, this system facilitates the arrival containerstransporting by waterway transportation and leaving the system by road transportation. The "Arrival" module is the first module of this system. As same as the "Arrival" module of Chiang Khong and Mae Sai systems, the random exponential distribution is used for defining the arriving time of the containers entering its system.

The next module is the "LiftUp" module. It is to lift up the arriving containers from a ship when this module is idle; otherwise it needs to be wait. Then, the provided facilities of the system will deliver the containers to the next sub-module that is the product declaration.

"CustomCheck"module is the module checking the invoice list, the invoice verification, the import invoice generation, and payment. All sub-modules are as same as in the Chiang Khong and Mae Sai systems.

To distribute these containers, 80% of containers can leave the system due to the limitation of available trucks. Other containers will be on hold [1], [17].

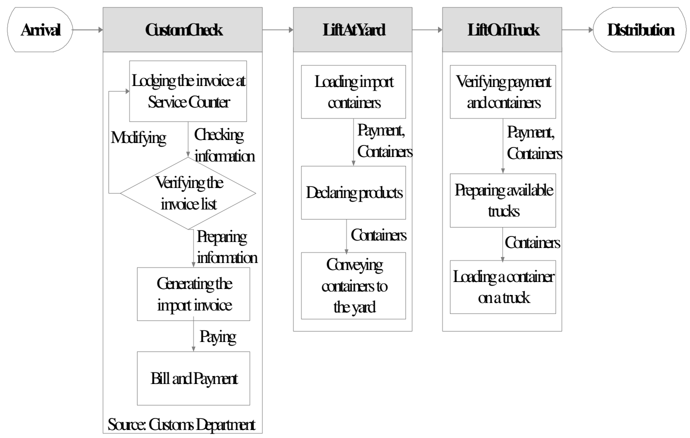

Figure 6.Modules and sub-modules of Chiang Khong and Mae Sai systems [12]

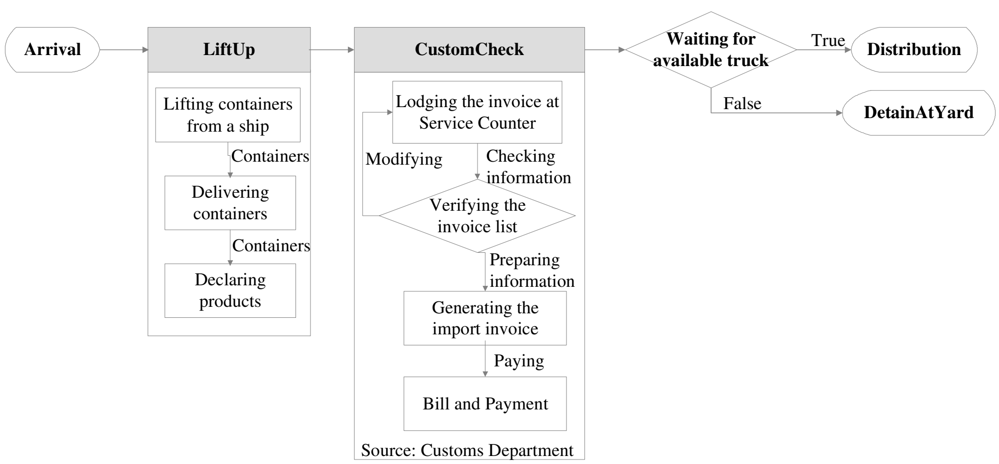

Figure 7. Modules and sub-modules of Chiang Sean system [12]

4.3. Setting Parameters of the Developed Systems

The random exponential distribution and triangular distribution techniques are the simulation techniques. These techniques are used to identify the arriving time of products entering the systemand the capability of the system, respectively.

The random exponential distribution will be used to manage the interval time for both systems at "Arrival" module as happened in the real system.The equationsof the exponential distributionare described below:

$$x: \Omega \rightarrow S$$

x is a random variablethat is functioned by Ω (the basic simple space); S is known as the state space of x composing of all possible values. With a standard deviation of 1 and 0 mean, x random number goes under a standard normal distribution.

$$F_x(x) = 1 - e^{-\lambda x}, x \geq 0$$

x exponential random variable provides values in the positive half-line. In Figure 8, the probability density of exponential distribution technique is described. Arrival containers will be randomly entered into the system but its interval is closed to the given mean interval.

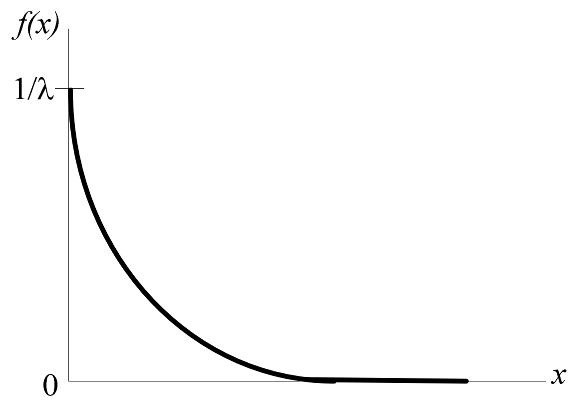

Figure 8 Probability density function of exponential distribution

The triangular distribution technique is used for simulating all processes in the product distribution systems such as "CustomCheck", "LiftAtYard", "LiftOnTruck", and "LiftUp" modules. This technique is effective to simulate the process when the processing time of the process cannot specify, so the processing time estimation is used as the minimum, most likely and maximum time. The equation is described below.

$$f_x(x) = \begin{cases} \dfrac{2(x-a)}{(b-a)(c-a)}, & if\ a \leq x \leq c \\ \dfrac{2(b-x)}{(b-a)(b-c)}, & if\ c \leq x \leq b \\ 0, & otherwise \end{cases}$$

x is a triangular random variable that attributes values in an interval [a, b] and the mode value [m]. The probability sequentially raises up in the subinterval [a, m], and sequentially goes down in the subinterval [m,b] (detailed in Figure 9). This technique function is usedby $Tria(a, b, c)$.

In addition, these two simulation techniques are the functions in ARENA;Random(Expo) and TRAI(minimum, most likely, maximum). In the developed system models, the working hours are 12hours per day for simulation or 720minutes per day. As described in the previous sections, the process modules of these developed system will be designed and simulated by ARENA according to the field survey and data collection.

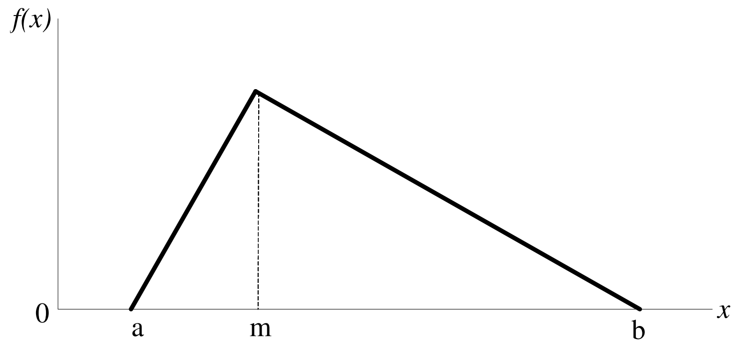

Figure 9 Probability density function of triangular distribution

Table 2.Setting parametersof Chiang Khong and Mae Sai systems in ARENA

Module Name	Description	Formula
Arrival	Interval arrival time of a container	Random(Expo)
CustomCheck	Process time at the custom	TRAI(minimum, most likely, maximum)
LiftAtYard	Process time for lifting a container to the yard	TRAI(minimum, most likely, maximum)
LiftOnTruck	Process time for lifting a container on a truck	TRAI(minimum, most likely, maximum)
Distribution	Leave the system	

In Table 2, it is the detail of modules in the product distribution system of Chiang Khong and Mae Sai DCs and it is the detail of the functions in each module.

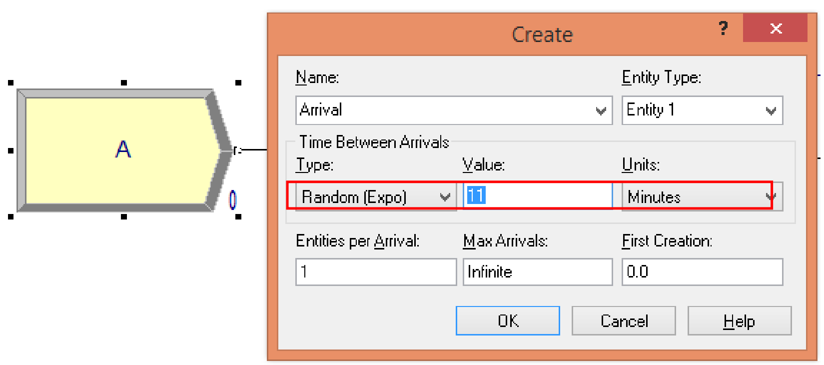

Figure 10 setting "Arrival" module

The example for setting parameters is for Chiang Khong DC at "Arrival" module as in Figure 10. The type of function usesRandom(Expo) so that the interval of arriving time fora container will be randomly generated. The value is 11minutes. It is from the highest volume of the arrival products in 2012 of Chiang Khong custom houses(39,700tons in July) divided by 20tons(converting a weight of ton to a container) and divided with 720minutes working time perday. Therefore, the value for Random(Expo) formulation is set as 11. The value of Chiang Sean and Mae Sai systems is 8.4, and 16.4minutes, respectively

On the other hands, in Figure 11, "CustomCheck", "LiftAtYard", and "LiftOnTruck" modules are the modules of Chiang Khong and Mae Sai systems that set the action as "Seize Delay Release".

This actionis to seize the system resource for processing when a container enter the module. When a container is in process, other container will be automatically set as delay in a queue.The delay type of these modules will use the function *TRAI(minimum, most likely, maximum)* as Triangular probability distribution formulation for processing. Thisfunctionwill define the probability distribution of a container consuming time in these modules.The minimum, most likely and maximumvalues of"CustomCheck" modulein Chiang Khong DC will be set *TRAI(15,20,25)* because the custom service counter generallyspends15minutes for completing the process, 20minutes for the delay time, and 25minutes for the maximum duration ofa process. "LiftAtYard" and "LiftOnTruck" modules of Chiang Khong system set the value of *TRAI(minimum, most likely, maximum)* as *TRAI(8,12,16)*. For Mae Sai system, the value in "CustomCheck" set as *TRAI(15,20,25)* while "LiftAtYard" and "LiftOnTruck" modules set as *TRAI(8,10,12)*.

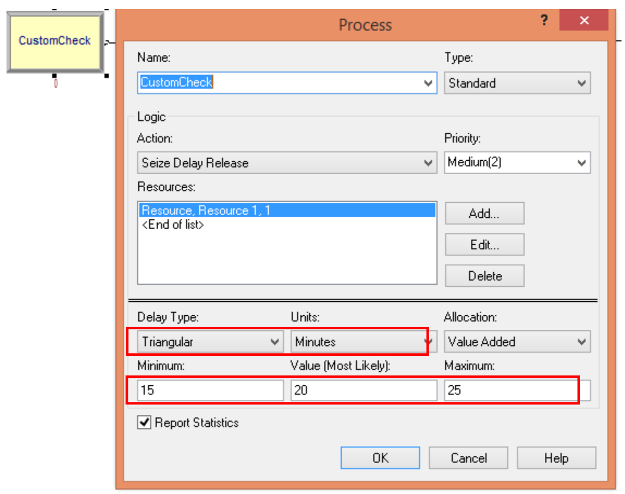

Figure 11 Setting "CustomCheck" module

For the modules of Chiang Sean system, it details in Table 3. "Arrival" module will use the function of*Random(Expo)*as detailed above. "LiftUp" and "CustomCheck" modules use *TRAI(minimum, most likely, maximum)*function. "LiftUp" module sets as*TRAI(15,20,25)*and "CustomCheck" module set as same as in "CustomCheck" module of Chiang Khong and Mae Saisystems. Before delivery the completed containers, "Decide" module is used to decide 80% for delivery by available trucks, but 20% for detention when trucks cannot be provided.

Table 3.Setting parameters of Chiang Sean system in ARENA

Module Name	**Description**	**Formula**
Arrival	Interval arrival time of a container	Random(Expo)
LiftUp	Process time for lifting up a container from a ship	TRAI(minimum, most likely, maximum)
CustomCheck	Process time at the custom	TRAI(minimum, most likely, maximum)
Decide	Consideration for delivery or detention	80% for delivering a container (True) 20% for detaining a container (False)
Distribution	Leave the system	

4.4. Model Application

In this study, we develop the product distribution systems for three new DCstoevaluate the system capability.A scenario is proposed to simulate the developed systems by increasing the percentage of arrival products from the south of China because there is no implementation at three new DCs, so the arrival product volumes is no recorded. We systematically assume the increase of arrival products from the base data to25%, 50%, 75%, and 100%, respectively.We expect the simulation result from this scenario can describe the system capacity as well as the entering product volumes from the south of China. We also expect the problem on the systems will be reflected, so the solutions can be offered to prevent its problemand the developed systems can be contributedto similar systems.

5. SIMULATION RESULT

To evaluate the system capacity by increasing the volumes of arrival products from the base data to 25%, 50%, 75%, and 100%, ARENA is implemented to simulate the product distribution systems of three new DCs for one working day (12hours or 720minutes per day).

In Table 4, it shows the simulation result of Chiang Khong system by increasing arrival products from base data to 25%, 50%, 75%, and 100% .There are the waiting truck in each process modules. The finished containers in each state of increasing arrival products slightly increase. Moreoever, many trucks are waiting for processing in "CustomCheck" module higher than "LiftAtYard" and "LiftOnTruck" modules.

Table 4.Simulation result of Chiang Khongsystem

Increasing arrival truck	**Waiting number in a module (truck/12hr)**			**Number out from the system (truck/12hr)**	**Total number of arrival truck (truck/12hr)**
	CustomCheck	**LiftAtYard**	**LiftOnTruck**		
25%	12	11	2	54	79
50%	28	12	3	56	99
75%	30	14	2	56	102
100%	53	12	1	57	123

In Table 5, it shows the simulation result of Chiang Sean system. The waiting number of trucks are mostly in "LiftUp" module while it is very few in "CustomCheck" module. The transported trucks out from its system is remain stable when the arrival trucks are increased. It can be noticed that Chiang Sean system faces the same problem of Chiang Khong system.

Table 5.Simulation result of Chiang system

Increasing arrival truck	**Waiting number in a module (truck/12hr)**		**Number out from the system (truck/12hr)**	**Total number of arrival truck (truck/12hr)**
	LiftUp	**CustomCheck**		
25%	34	1	33	69
50%	40	1	33	74
75%	52	1	33	86
100%	70	1	34	105

In Table 6, it reports the simulation result from Mae Sai system. The waiting number is few. Mae Sai system can mostly release the finished trucks out from the system and the number of finished trucks are increased following the increase of arrival trucks.

Table 6.Simulation result of Mae Sai system

Increasing arrival truck	Waiting number in a module (truck/12hr)			Number out from the system (truck/12hr)	Total number of arrival truck (truck/12hr)
	CustomCheck	LiftAtYard	LiftOnTruck		
25%	5	1	1	59	66
50%	6	2	1	61	70
75%	8	2	1	61	72
100%	15	2	1	66	84

In Figure 12, it illustrates the number of waiting trucks in each module and the number of released truck of Chiang Khong system. The number of waiting trucks in the first module ("CustomCheck") is very high and it dramatically increases when increasing the arrival trucks into the system. The number of waiting trucks in the second module ("LiftAtYard") is different from the waiting trucks in "CustomCheck" module over 70% while the number is very few in the third module ("LiftOnTruck"). It indicates that only "CustomCheck" module confronts the long queue of waiting truck as called the bottleneck problem.The system capability of Chiang Khong system can maintain to release the finished trucks from the system well. Until the increase of arrival trucks reaches 100%, the system capability becomes overloaded because the waiting trucks numbers are similar to the released truck numbers.

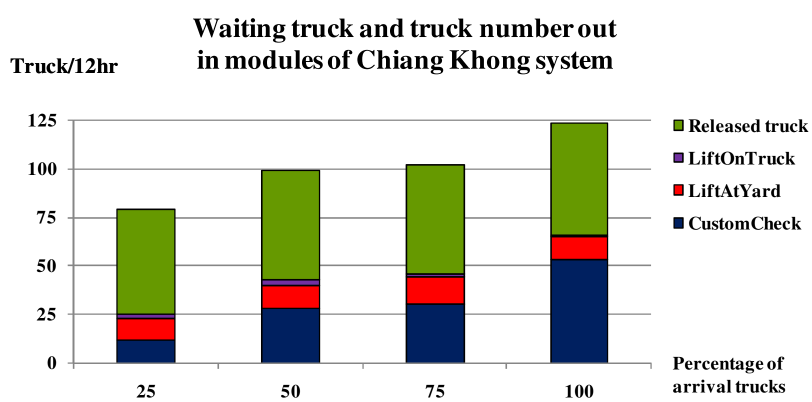

Figure 12. Waiting truck in each module of Chiang Khong model

For the Chiang Sean system, the bottleneck problem is more than other systems because the number of released trucks is less than the number of waiting trucks for 100% in particular in the first module ("LiftUp") when the increasing arrival trucks entering the system are 100% as in Figure 13. However, it is very few trucks waiting to process in the second module. Therefore, it can evaluate that the bottleneck problem is very serious for Chiang Sean product distribution system and "LiftUp" module is the only module that causes the large number of waiting trucks in its system.

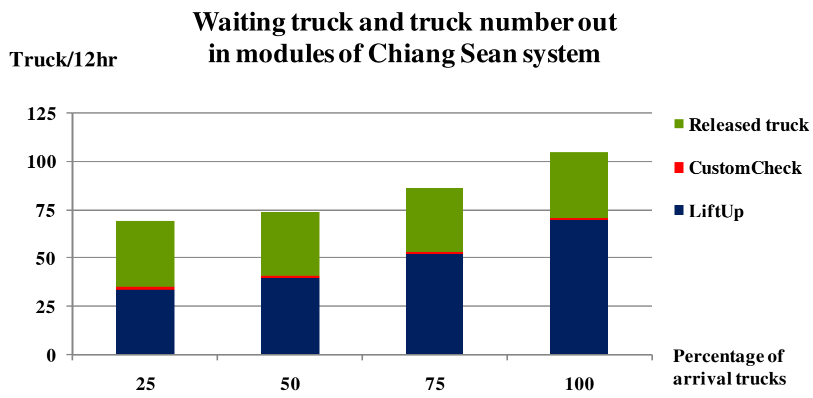

Figure 13. Waiting truck in each module of Chiang Sean model

Mae Sai system is the only system that can manage its system very well as demonstrated in Figure 14. The bottleneck problem does not occur in its system because few trucks are waiting in its modules. The number of released trucks increases following the increasing arrival trucks As a result, Mae Sai system can maintain its system capability very well, it suggests that the percentage of increasing arrival trucks should be concerned to increase for 150% or 200% in order to evaluate its capability.

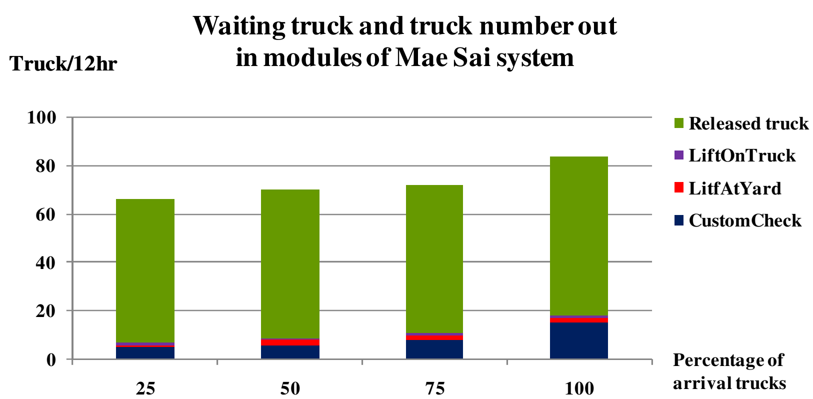

Figure 14. Waiting truck in each module of Mae Sai model

6. CONSIDERATION

According to the computational results, there are two considerations on the capability of the product distribution systems in Chiang Khong, Chiang Sean, and Mae Sai DCs.

6.1. Consideration on Chiang Khong and Chiang Sean systems

The first consideration is from the simulation results of Chiang Khong and Chiang Sean systems. With the efficiency of the system modelling, the results reflect the bottleneck problem occurring in the systems. Most waiting trucks are in the first module of these systems, so we finalize proposing to increase the capability in the first module. At the "CustomCheck" module of Chiang

Khong system and the "LiftUp" module of Chiang Sean system, we will add one more service in the modules to notice the change of system capability.

With the triangular distribution function in ARENA, the "CustomCheck" module of Chiang Khong system will set the minimum, most likely and maximum values as in Figure 15.in order to add one more service counter.

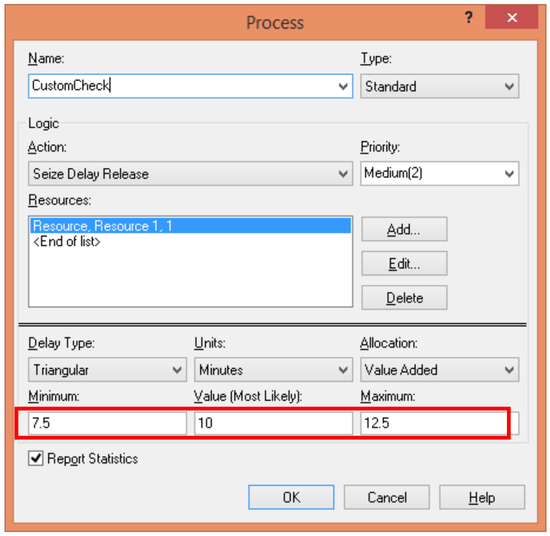

Figure 15. Parameter setting on "CustomCheck" module of Chiang Khong system

The simulation result of Chiang Khong system following the proposed scenario is detailed in Table 7. It shows that the waiting trucks in the first module of Chiang Khong system is sharply reduced, but the adding one more service counter at only the first module causes the long queue waiting to be processed in the second module instead. In addition, the number out from the system is not different from the regular system.

Table 7. Result of Chiang Khongsystem by adding one more service at its first module

Increasing arrival truck	**Waiting number in a module (truck/12hr)**			**Number out from the system (truck/12hr)**	**Total number of arrival truck (truck/12hr)**
	CustomCheck	**LiftAtYard**	**LiftOnTruck**		
25%	3	13	1	56	73
50%	5	30	1	56	92
75%	7	47	1	57	112
100%	5	56	2	57	120

On the other hands, the minimum, most likely and maximum values will be set in the "LiftUp" module of Chiang Sean system as in Figure 15 for adding one more service counter.

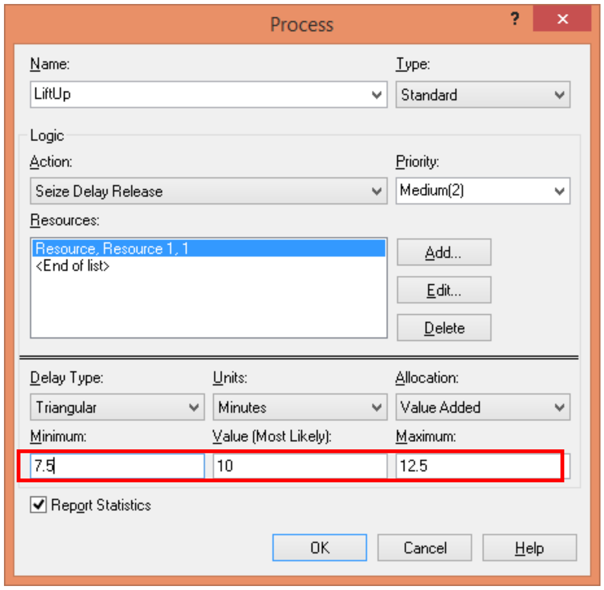

Figure 15. Parameter setting on "LiftUp" module of Chiang Sean system

After experimenting the proposed scenario, the simulation result of Chiang Sean system results in Table 8. The situation is similar to the situation of Chiang Khong system. The bottleneck problem in the "LiftUp" module is benign, but the next module has the serious problem on the long queue of waiting trucks instead. In fact, the number out from the system does not change from the regular system.

Table 8. Result of Chiang Sean system by adding one more service at its second module

Increasing arrival truck	**Waiting number in a module (truck/12hr)**		**Number out from the system (truck/12hr)**	**Total number of arrival truck (truck/12hr)**
	LiftUp	**CustomCheck**		
25%	20	36	35	91
50%	34	41	36	111
75%	35	56	36	127
100%	36	88	36	160

6.2. Consideration on Mae Sai System

Another consideration is fromthe simulation result of Mae Sai system. It indicates that the capability of its system can manage with the increase of arrival products more than 100%. Therefore, the increase of arrival products should increase up to 150% or 200% to observe its capability.

With the random exponential distribution function in ARENA, the "Arrival" module of Mae Sai system will set the value for 6.6 and 5.5minutes as in Figure 16 and 17 in order to increase the arrival product volumes into the system for 150% and 200%, respectively.

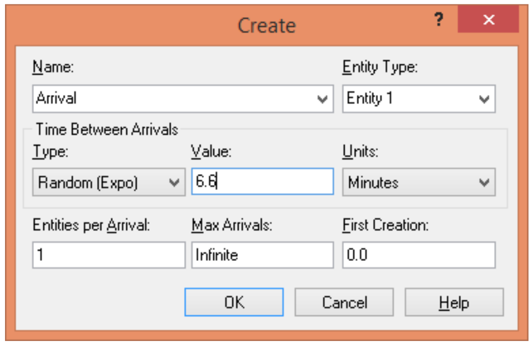

Figure 16. Parameter setting on "Arrival" module of Mae Sai system for 150% of increasing arrival product volumes

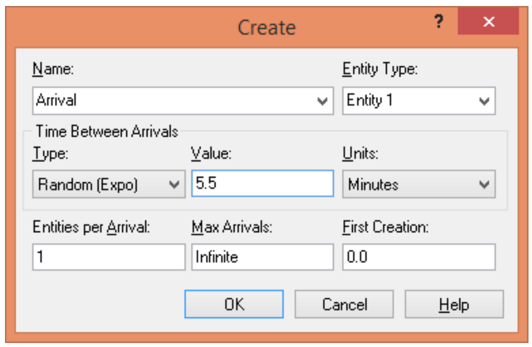

Figure 17. Parameter setting on "Arrival" module of Mae Sai system for 200% of increasing arrival product volumes

Table 9. Result of Mae Sai system when increasing arrival products up to 200%

Increasing arrival truck	**Waiting number in a module (truck/12hr)**			**Number out from the system (truck/12hr)**	**Total number of arrival truck (truck/12hr)**
	CustomCheck	**LiftAtYard**	**LiftOnTruck**		
25%	5	1	1	59	66
50%	6	2	1	61	70
75%	8	2	1	61	72
100%	15	2	1	66	84
150%	18	2	2	68	90
200%	36	2	2	68	108

The simulation result from this scenario is shown in Table 9. It indicates that Mae Sai system can maintain the system capability well when the increase of arrival products is less than 200%. It is because the waiting trucks in the first module is more than 50% of the number out when the increasing arrival products are 200%.

7. Conclusion and Discussion

Due to the specific objectives of this research, the first specific objective isthe development of product distribution systems for three new DCs for evaluating the system capability of the system, and the developed systems are expected to reflect the problem that affects the system capability.

There are two product distribution systems successfully developed. The first developed system is provided for Chiang Khong and Mae Sai DCs where facilitate the road transportation. Another developed system is for Chiang Sean DC where facilitates the waterway - road transportation. The random exponential distribution and triangular distribution techniques are the proposed simulation techniques that are used to simulate and evaluate the systems.

The increasing arrival products entering the systems are estimated to increase proportionally from the base data to 25%, 50%, 75%, 100% for observing the capability of the systems. The simulation results indicate that the bottleneck problems particularly occurs in the first module of Chiang Khong and Chiang Sean system while Mae Sai system can maintain its system well. Moreover, with the efficiency of the proposed simulation techniques, the first module of Chiang Khong and Chiang Sean system is adjusted to add more service while Mae Sai system is increased the arrival products to 150% and 200. As proposed scenario for system evaluation, the bottleneck problem occurs in the second module of Chiang Khong and Chiang Sean systems instead, and Mae Sai system seem facing the bottleneck problem when the increasing arrival products are 200%.

In conclusion, the developed systems for three new DCs are successfully developed by ARENA application and the proposed simulation techniques are effectively used to evaluate the problem occurring in the system, so the developed systems associated with the proposed simulation techniques can be effectively contributed to similar systems.

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